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FOREST PLANTING ON STRIP-MINED LAND

IN KANSAS, MISSOURI, AND OKLAHOMA

BY

F. BRYAN CLARK

CENTRAL STATES
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Frontispiece.--Forest planting is one way to reclaim strip-mined land. Part of 2,000 acres of black walnut plantings made by the Civilian Conservation Corps in southeastern Kansas from 1934 to 1937.

FOREST PLANTING ON STRIP-MINED LAND IN KANSAS, MISSOURI, AND OKLAHOMA

by

F. Bryan Clark[1/]

INTRODUCTION

Forestation is one way to reclaim land that has been strip-mined for coal in Kansas, Missouri, and Oklahoma (frontispiece). Although some of this land supports stands of trees, it is apparent that natural reproduction will not always produce satisfactory forest stands. If forest crops are to be grown on strip-mined land, most areas will have to be planted. In 1947 the Central States Forest Experiment Station, in cooperation with local strip-mining companies, began a series of studies to find out which forest tree species are suitable for planting on strip-mined land in the three states.

The amount of land that has been mined in this region is small in relation to the total land area. However, the mining is concentrated in certain regions where it has created new land-use problems. Conditions for open-cut or strip-mining of coal are highly favorable in parts of Kansas, Missouri, and Oklahoma. In strip-mining, all of the strata overlying shallow deposits of coal are removed exposing the coal in an open pit. This method of mining accounts for most of the coal produced in the three states.

According to a survey (10)[2/] made in 1946, approximately 59,000 acres had been strip-mined to that date in the 3-state area (fig. 1). Since then several thousand more acres of land have been mined by this method. When the survey was made, only 4 percent of the strip-mined land in Kansas, Missouri, and Oklahoma could not be reforested because of the nature of the strip-banks. The surface of the banks on these "unplantable" areas contained much toxic acid material. The survey showed that approximately 46 percent of all strip-mined land in the area was barren of any vegetation. The remaining land supported some form of herbaceous or woody vegetation (table 1, p. 4).

The fact that strip-mined land is very rough is no obstacle to forest production. Deitschman and Lane (2) report that in Indiana some species of trees planted on strip-mined land may grow as well as or better than trees on unmined land. The conglomeration of materials that make up the "soil" on mined areas is generally

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1/ Forester, Northern Ozark Forest Research Center.

2/ Numbers in parentheses refer to Literature Cited, p. 27.

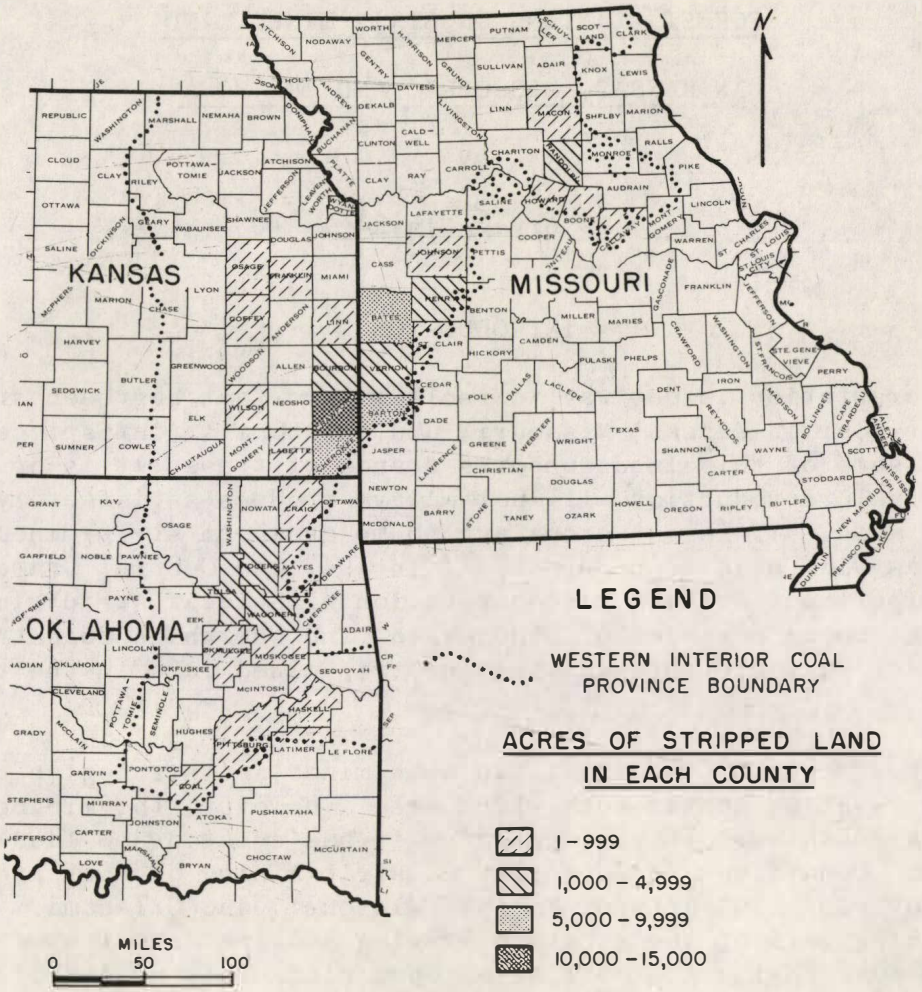


Figure 1.--Strip-mined land in Kansas, Missouri, and Oklahoma by counties and intensity of mining as of 1946 (10).

rich in most mineral nutrients except nitrogen. Trees established on strip-mined land in the three states will probably grow as well as or better than trees growing on undisturbed land.

The strip-mined land in this area is in a prairie-forest transition zone. The forests and the prairie are intermingled but the forests are concentrated along watercourses. Rainfall is favorable for tree production except that periodic droughts throughout the area may make tree establishment difficult.

Forestation is not the only way to rehabilitate strip-mined land. There are several other good uses for this land. Most of the areas contain abundant water, and excellent recreation areas can be developed. Several good orchards have been established in the area. Another highly promising use of such land in Kansas, Missouri, and Oklahoma, is forage production. Undoubtedly there is a place for all of these uses of strip-mined land.

SPECIES-SUITABILITY TEST

In the spring of 1947, 12 areas ranging in location from Huntsville, Missouri, to Tulsa, Oklahoma, were planted using 14 different forest tree species. The primary purpose of this study was to find out how well these species survive and grow on strip-mined land in the Kansas-Missouri-Oklahoma area. Such information will be valuable in determining which species are best suited for reclaiming strip-mined land.

"Soil" type, acidity, percent of soil-size particles (less than 2 millimeters in diameter), age of banks, and amount of natural cover at the time of planting are different for these 12 areas. Descriptive information on each planting area is found in table 4 (Appendix). Part of areas 3 and 8 were graded nearly level to test the effects of grading on the survival and growth of the planted trees.

The following species and classes of stock were used in the study:

Native

1-0[3/]	Black cherry (*Prunus serotina* Ehrh.)
1-1	Bur oak (*Quercus macrocarpa* Michx.)
1-0	Eastern redcedar (*Juniperus virginiana* L.)
1-0	Green ash (*Fraxinus pennsylvanica* var. *lanceolata* (Borkh.) Sarg.)
1-0	Sycamore (*Platanus occidentalis* L.)
	Black cherry seed (*Prunus serotina* Ehrh.)
	Black walnut seed (*Juglans nigra* L.)
	Bur oak seed (*Quercus macrocarpa* Michx.)

Non-native

1-0	Black locust (*Robinia pseudoacacia* L.)
2-0	Jack pine (*Pinus banksiana* Lamb.)
1-0	Loblolly pine (*Pinus taeda* L.)
1-0	Pitch pine (*Pinus rigida* Mill.)
2-0	Ponderosa pine (*Pinus ponderosa* Laws.)
1-0	Shortleaf pine (*Pinus echinata* Mill.)
1-0	Sweetgum (*Liquidambar styraciflua* L.)
1-0	Virginia pine (*Pinus virginiana* Mill.)

3/ The first number is the number of growing seasons the stock was left in the nursery seedbed and the second number is the number of years the stock was left in the transplant bed.

Table 1.--Area of strip-mined land by state and kind of vegetation, 1946

State	Barren	Herbaceous and shrubby plants	Forest		Total
			Natural	Planted	
	Acres	Acres	Acres	Acres	Acres
Kansas	10,150	9,362	3,345	2,325	25,182
Missouri	11,944	10,840	2,521	191	25,496
Oklahoma	4,782	2,759	563	212	8,316
Total	26,876	22,961	6,429	2,728	58,994
Percent	45.6	38.9	10.9	4.6	100.0

The native species used were those found growing in natural stands on strip-banks or on nearby areas. These species showed promise of producing merchantable crops. The non-native species were those that had grown satisfactorily in past plantings or that held some promise of being suitable for planting on strip-mined land. There are, no doubt, other native and non-native species that should be used in future trials in this region.

Each planting area contained approximately 4.7 acres divided into 42 plots. Plots were 70 feet square, large enough to plant 100 trees on a 7-by-7-foot spacing. Each species was assigned at random to three plots in each area. The side-hole method of planting was used.

Survival and height-growth measurements were taken after the first, second, and sixth growing seasons. Cause of mortality, when apparent, was recorded for dead trees. Topographic position was recorded for each planting spot.

Moisture conditions were generally favorable during the early part of the first growing season, but drought accompanied by high temperatures prevailed over all of the planting areas during the middle and late growing season.

The 1947 planting of shortleaf pine was considered a failure after one growing season; much of the mortality was attributed to poor planting stock. In the spring of 1948 the shortleaf pine plots were replanted with the same species. Black cherry seeding was a complete failure and the plots were replanted in the spring of 1948 with sycamore seedlings. Sweetgum was planted in area 12 in 1947 and again in 1948; both plantings were failures. Data from these

plantings are not included in the tables presented. Area 6 was eliminated from the 6-year remeasurement because it had burned-over at least four times.

Survival

The over-all survival for all species was 48.1 percent after one growing season. After two growing seasons survival averaged 41.0 percent and after six growing seasons 34.1 percent. For all practical purposes, survival after two growing seasons gives a good estimate of future plantation stocking.

Survival at the end of 6 years varied by areas and species (table 5 - Appendix). For all areas combined, survival ranged from 12 percent for ponderosa pine to 69 percent for black locust. For all species combined, survival ranged from 17 percent on area 3A to 55 percent on area 5.

Survival was poorest in the bottoms and on the ridgetops and best on the north- and east-facing slopes. The average survival for all species and all areas ranged from 26 percent in the bottoms to 40 percent on the north- and east-facing slopes after six growing seasons (table 6 - Appendix). There are some exceptions to this general trend. Black locust, for instance, had its highest survival on ridges, whereas black walnut, a moist-site species, had its lowest survival on ridges.

Natural vegetation, consisting of a host of herbaceous plants and a large variety of woody plants, occurred in various amounts on the planting areas. The density of vegetation in the immediate vicinity of each planting spot was estimated in terms of the percent of ground covered. Although there were variations among species (table 7 - Appendix) the average survival of all species after the first growing season was best (72 percent) when trees were planted in areas where 41 to 60 percent of the ground was covered with natural vegetation. The average survival was poorest (54 percent) where less than 20 percent of the ground was covered.

Mortality was 51.9 percent during the first growing season, 7.1 percent during the second growing season, and 1.7 percent on the average during the third to the sixth growing seasons, inclusive. The cause of mortality could seldom be determined, but evidence indicates that drought accompanied by high temperatures was the major cause. Cause of mortality varied by species and areas. (This will be discussed in a later section.) Mortality during the six growing seasons is shown in the tabulation below by causes for all areas and all species:

Cause	Percent mortality
Competition	1.8
Erosion	2.8
Standing water	2.5
Toxic acidity	6.1
Animals[4/]	.9
Drought and others[5/]	51.8
Total	65.9

Height Growth

Total tree height after six growing seasons varied widely among species and to a lesser extent among areas (table 8 - Appendix). The average height for all areas by species varied from 2.5 feet for ponderosa pine to 16.7 feet for black locust. Large differences in the early growth rate for the various species are to be expected. Of all species planted only black locust had grown fast enough to produce closed stands at the end of 6 years. Some differences in growth rate between the areas for the various species are large and these variations can be attributed to differences in site quality. On the average, trees made the poorest growth on the ridgetops, and the best growth on the slopes (table 9 - Appendix).

MIXED-PLANTING STUDY

A Mixed-Planting Study with black walnut as the principal species was begun on strip-mined land in Cherokee County, Kansas, in the spring of 1950. The primary purpose of this study is to determine what effect black locust and four other species have on the growth and quality of wood in black walnut trees.

Earlier plantings of black walnut have shown that this species can be used to reclaim strip-mined land in this area. From 1933 to 1937 the Civilian Conservation Corps planted about 2,900 acres of strip-mined land with walnut seed. In 1946 approximately 2,000 acres (9) of these plantings contained fairly well-stocked stands of walnut (fig. 2). Trees in these plantations have grown satisfactorily but persistent lower branches have reduced the quality of the wood being produced in many stands. By planting walnut in mixed stands the trees should develop under more dense conditions and produce clear wood at an earlier age.

4/ Includes rabbits, rodents, and insects.
5/ Drought was probably the major factor in this class.

Figure 2.--An excellent young stand of black walnut established from seed in 1935.

The study area was mined in 1946 for Number 14[6/] coal. The surface material of the strip-banks consists of shale and clay, and about 31 percent of this material was soil-size particles. The pH averaged about 7.5.

Each of five species mixtures was planted on four plots; the total area planted was 23 acres. The side-hole method of planting was used on a 7-by-7-foot spacing. All of the planting stock was seedlings except walnut. Three black walnut seeds were placed in each planting spot in an effort to get a fully stocked plantation. Species used, other than walnut, were:

1-0	Black locust
2-0	Bur oak
1-0	Eastern redcedar
1-0	Green ash
1-0	Sycamore

6/ The numbers used for the various coal seams are those most commonly used in the three states (10).

Although the study was primarily a mixed-planting test, early survival records were made and the results are presented for comparison with the Species-Suitability Test. The weather conditions during the first growing season were probably more favorable for seedling establishment for the Mixed-Planting Study than for the Species-Suitability Test.

Survival

Survival at the end of the first growing season was satisfactory for all species except black walnut and eastern redcedar (table 2). A walnut planting spot was considered to have "survived" if it contained at least one live seedling. Survival after the second growing season was essentially the same as the survival after the first except for black walnut and bur oak.

Table 2.--Survival after the first and second growing seasons by species (Mixed-Planting Study)

Species	Survival	
	First year	Second year
	Percent	Percent
Black walnut	45	82
Black locust	69	71
Bur oak	86	67
Eastern redcedar	40	38
Green ash	97	96
Sycamore	81	80
Average	70	72

Bur oak had an additional 19 percent mortality the second year. At the end of the first growing season many of the bur oak seedlings, although alive, had poor vigor. This is attributed to the poor root systems of the planting stock.

Black walnut had a large increase in survival (37 percent) due to delayed germination. Although delayed germination is not uncommon when black walnut seeds are used, such a large amount was not expected, particularly since the seeds had been stratified.

This holdover of seed in a dormant condition from one growing season to the next was probably due to the dry conditions that existed from March, when the seeds were planted, until July. Evidently many of the planting spots were dry to at least the depth the seeds were planted during the normal period of germination.

The second year survival data were summarized by topographic position. The relationships between survival and topography were about the same as those in the Species-Suitability Test.

FACTORS AFFECTING SURVIVAL AND GROWTH OF PLANTED TREES

There are many things that may affect the survival and growth of trees planted on strip-mined land. If the more important of these can be recognized before an attempt is made to establish a plantation, the potential tree planter may be able to save himself some unnecessary losses. Some causes of tree mortality cannot be forecast, but they are pointed out here as hazards to plantation success. Most of the information to be discussed was gained from the two experimental plantings described; however, some supplemental information obtained from experience in other localities is also included.

Acidity

One of the most important site characteristics to be considered in reclaiming strip-mined land is the acidity of surface materials. Various strata removed in mining, usually those closely associated with coal seams, contain such sulfur-bearing compounds as pyrite, marcasite, and other polysulfides. Upon exposure to air these compounds oxidize and in the presence of water produce sulfuric acid. A pH of less than 4.0 is generally considered toxic to most forest trees. Fortunately there are relatively few areas in Kansas, Missouri, and Oklahoma that are classified as unplantable due to toxic acidity. Limstrom (6) has reported that approximately 2 percent of the strip-mined land in Kansas, Missouri, and Oklahoma as of 1946 had soil classed as toxic, 2 percent marginal, 70 percent acid, 13 percent calcareous, and 13 percent mixed (see footnote 1 on table 4 in the Appendix for classification).

Acidity of newly mined areas may not give the correct impression of future acidity. Freshly exposed material will not have had sufficient time to oxidize. Planting may well be deferred on such areas; however, there are methods described by Deitschman and Lane (2), Deitschman and Neckers (3), and Kohnke (5) for predicting future toxic acidity by approximating the relative amounts of sulfur in newly exposed materials.

In the Species-Suitability Test, mortality for all species and all areas due to toxic acidity averaged 6.1 percent but varied from 0.4 to 26.2 percent for areas 12 and 3A, respectively.

In planting it is important to be able to recognize and avoid toxic acid spots. Such spots can be easily recognized when the surface is dry (fig. 3). Sulfuric acid withdraws moisture from the atmosphere and the acid spots appear wet or "greasy." Unfortunately toxic spots cannot always be recognized because the surface may be moist at the time of planting or the acid material may be buried by a thin covering of soil.

Figure 3.--The dark spots that have been circled on the first bank are toxic acid spots and should not be planted.

Texture

Surface texture of strip-mined land depends upon the type of overburden, method of mining, and the age of the banks. Most of the banks in Kansas, Missouri, and Oklahoma are loams or silty shales (fig. 4); there are some clay banks and a few that are classed as sand. Most of the shales are fairly soft and decompose rapidly. A few years of weathering generally increases the percentage of soil. In the Species-Suitability Test, the amount of soil-size particles ranged from 17 to 57 percent.

Figure 4.--The surface material is generally composed of a high percentage of stones and shale. Approximately 30 percent of the material on this bank was soil-size.

There was no apparent relationship between the percent of soil-size particles and survival; however, the study was not designed to test this specific factor and there were many confounding influences. Banks containing a fairly high percentage of "soil" have a better moisture retention capacity than banks containing a lot of stone. Consequently, species having a high moisture requirement should not be planted on banks with a small percentage of soil-size particles.

Texture also has an influence on erodability that may affect the survival and growth of planted trees. Mortality due to erosion averaged 2.8 percent for all species on all areas and ranged as high as 14.6 percent on area 4. This area was planted within a year after stripping. Sheet and gully erosion were still active 6 years after planting on all plots except those planted with locust. Black locust had less mortality due to erosion on this area than any of the other species. Stands of this species had closed canopies and a small build-up of litter and were the only stands providing protection against erosion.

Erosion not only exposes the roots of seedlings but it also causes seedlings planted in bottoms to be smothered by silt. Trees should not be planted in narrow bottoms if erosion is active. Newly created banks, especially those containing a high percentage of soil-size particles, should not be planted until they show signs of stabilizing (fig. 7A, p. 15). Most banks in this area can be planted within 2 to 5 years after mining.

Grading

Two areas, 3 and 8, in the Species-Suitability Test were used to find out how grading strip-banks affects the survival and growth of planted trees. Area 3B was graded with a bulldozer just prior to planting while area 8B was graded with a dragline when the area was mined in 1939. Soil moisture data were taken during the 1948 growing season on graded and ungraded portions of area 8.

Grading reduced survival and height growth in both areas. The all-species, 6-year survival on area 8 was 40 percent for the ungraded part and 28 percent for the graded. The over-all survival on area 3 was 17 percent for the ungraded part and 18 percent for the graded. However, mortality due to toxicity on area 3 was 13 percent for the graded part and 26 percent for the ungraded. When the area was graded much of the toxic material was "buried." If this confounding effect is removed from survival figures by disregarding trees that were planted in toxic acid spots, the survival for all species at the end of 6 years was 24 percent on the ungraded part and 23 percent on the graded part.

Average heights after 6 years on areas 3 and 8 for the various species are in general greater for the ungraded sites (table 8 - Appendix). Using black locust--the species with the most rapid growth--for comparison, height growth was 24 percent and 19 percent greater on ungraded areas 3 and 8, respectively, after 6 years (fig. 5).

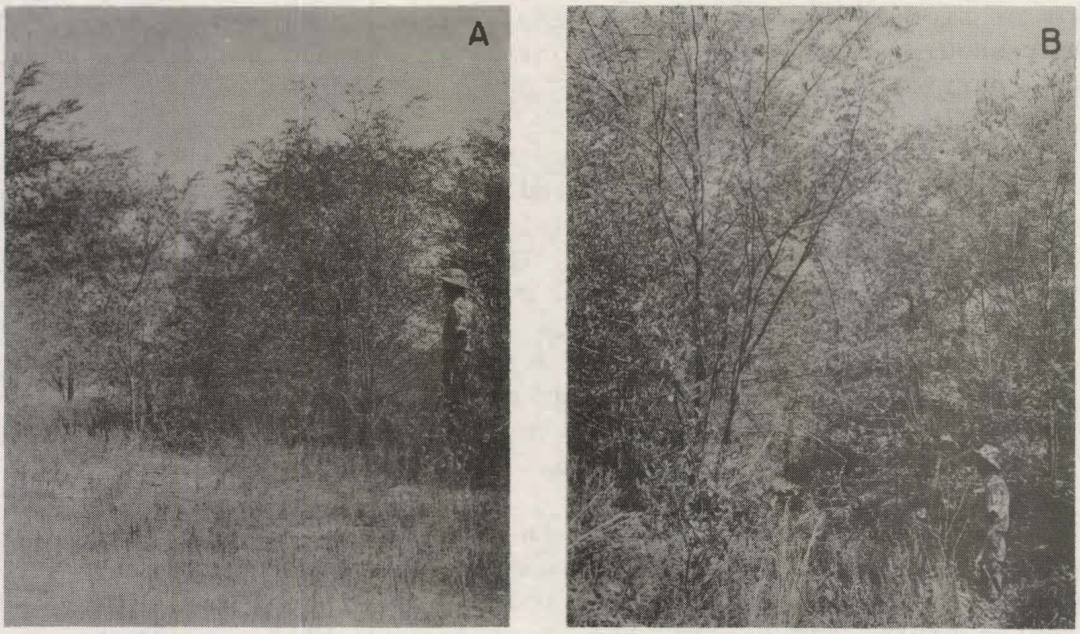


Figure 5.--Grading retards growth of trees: A, 6-year-old black locust on the graded part of area 8 grew more slowly than B, trees planted on adjacent undisturbed banks of the same area.

The moisture data taken on area 8 have been published by Limstrom (7) along with information from additional grading studies in other locations. It was found that the moisture conditions on ungraded banks were better than on graded banks. On area 8, moisture was deficient for longer periods on the graded than on the ungraded sites. Conditions of complete saturation following periods of heavy rainfall were more prolonged on the graded sites. Lack of moisture over long periods kills seedlings, and waterlogged conditions tend to decrease the growth rate. These poor moisture conditions on graded banks have been attributed to compacting by heavy machinery and to cementing of the surface due to poor drainage.

Topographic Position and Aspect

The effect of topographic position and aspect on survival was about the same for both studies. It was found that survival was poorest in the bottoms and on the ridgetops and best on the slopes (table 6 - Appendix). The differences in survival were generally not large and the greatest effect was apparent on conifers.

The causes of increased mortality on ridgetops and in bottoms are quite different. Ridgetops are subject to longer dry periods and bottoms are subject to periods of saturation. Since ridges are drier, they are more likely to be barren with no protection from high surface temperatures that may be lethal. Herbaceous growth is usually abundant in the bottoms, often to the extent of being injurious to many species, particularly conifers.

Trees, except possibly black locust, should not be planted within 5 feet of narrow ridgetops (fig. 6). Narrow bottoms should not be planted where there is a danger from siltation or standing water. Hardwoods rather than conifers should be planted in the broader bottoms and, for the best growth and highest returns, the "better" hardwoods, such as black walnut, should be planted along the lower slopes. Species such as black locust, planted for post production and site improvement, may well be planted on the upper slopes. These recommendations assume mixed plantings will be made; the feasibility of such plantings will be discussed in a later section.

Cover

Strip-mined land has varying amounts and types of natural cover depending largely on the age of the banks, seed source, and the physical and chemical conditions of the surface material. According to Limstrom (6) in 1946, 46 percent of the strip-mined land in the Kansas-Missouri-Oklahoma area was barren, 39 percent had various amounts of herbaceous cover, and 15 percent supported natural and planted stands of trees (table 1). Banks classed as barren were generally areas mined in recent years.

Catalpa trees in the valleys and on lower slopes have grown so rapidly that 200 to 300 posts per acre can be removed in thinning.

Trees on the ridgetops have grown very slowly.

Figure 6.--Effect of topography on the growth of 12-year-old planted catalpa.

The abundance of land supporting some natural vegetation indicates that many plantings will have to be made where some cover is present. In the Species-Suitability Test, the estimated amount of natural cover at the time of planting ranged from 5 percent to 95 percent among areas (fig. 7). The effect of cover on survival depends primarily on the species used and the weather conditions during the first year or two after planting. Once the trees have become established, weed competition should have a negligible effect on survival. Data presented in table 7 (Appendix) show the effects of various amounts of vegetation on the different species. Practically all species had better survival growing in moderate amounts of vegetation. Vegetation protects the seedlings from the extremely high surface temperatures that are common in this area. However, as the amount of vegetation increased, several species had an increase in mortality. Certain species are better able to compete with natural vegetation for moisture and light.

Black locust and ponderosa pine had the greatest increase in mortality under heavy cover. In the Mixed-Planting Study, it was found that sycamore mortality was highest under heavy competition. Such species as black walnut, green ash, and bur oak can be planted where natural cover might affect survival of other species. Where competition is heavy it is desirable to use fairly large, well-rooted planting stock.

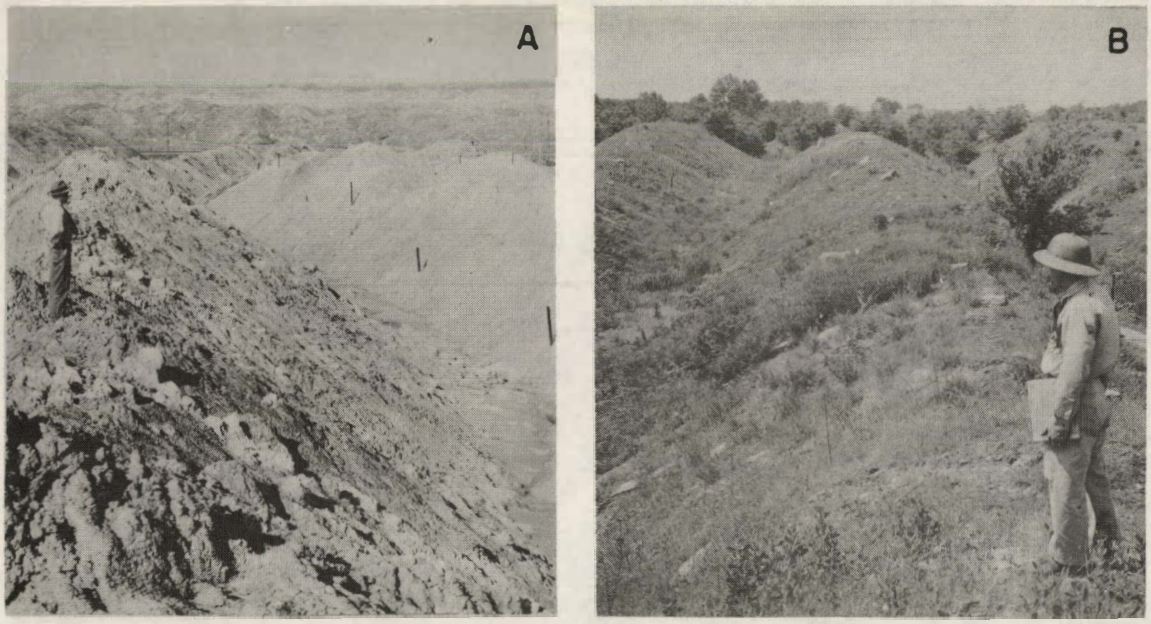


Figure 7.--The amount of natural cover varied from 5 to 95 percent among planting areas: A, 1 year after stripping. Area 4 was mined in such a fashion as to place soil and sub-soil on the surface. Very little vegetation was present and erosion was severe. Planting should be deferred on such areas. B, 13 years after stripping. Area 12 was stabilized and almost completely covered by volunteer vegetation.

Tree Species

Survival ranged from complete failure for the 1947 and 1948 plantings of sweetgum to 96 percent for green ash in the 1950 plantings.

A comparison of the survival of native and non-native trees used in the Species-Suitability Test provides an excellent general rule for selecting species to use in planting (table 3). Generally, native species had better survival than non-native species. The survival of non-native species other than black locust was 25 percent. On this basis, the survival of native trees was nearly twice as high as non-native trees. This does not mean that species not native to the area should not be planted. Black locust, for instance, can be easily established and will grow rapidly. However, untried exotics should not be planted wholesale until they have been tested in small-scale plantings.

Table 3.--Six-year survival of planted seedlings on all planting areas (Species-Suitability Test)

Species	Survival
	Percent
Native	
Black cherry	35
Bur oak	42
Green ash	63
Sycamore	38
Eastern redcedar	42
Average	44
Non-native	
Black locust	69
Jack pine	24
Loblolly pine	20
Pitch pine	32
Ponderosa pine	15
Shortleaf pine	36
Virginia pine	25
Average	32

Weather

Rainfall greatly influences the survival and growth of planted trees. Drought, accompanied by extremely high temperatures, was in all likelihood responsible for much of the mortality in the planting experiments. Survival was comparatively low in the Species-Suitability Test, which was established in a dry year. The growing season in which the Mixed-Planting Study was established had more favorable moisture conditions and survival was good. The difference in survival between these studies can be logically attributed to the differences in the growing seasons in which the plantings were established.

Drought, unless extremely severe, does not have a serious effect on the survival of trees 2 or more years old. There was no apparent increase in mortality due to drought after the prolonged dry conditions that prevailed over the entire area in 1952.

If much acreage is to be planted, the risk of plantation failure due to extreme weather conditions can be decreased by extending the planting over several years.

Other Factors

The locust borer (Megacyllene robiniae Forst.) has severely infested black locust on some of the areas. Most of the plantings of locust have been infested to some extent, but mortality due to borers has been low. The average mortality in the Species-Suitability Test was only 2.6 percent and ranged up to 5.6 percent for an individual planting area. Even though mortality is not high, severe infestations seriously affect tree form and the time required to produce posts. Some areas have produced post crops in a short time with little effect from borers, but other areas, seemingly under the same conditions, fail to produce a merchantable crop at all. Fortunately black locust can play another important role in strip-mine plantings; it can serve as a nurse crop to protect and improve the site for more promising species.

Nantucket pine tip moth (Rhyacionia frustrana (Comst.)) was found on all species of pine in all areas. Shortleaf, Virginia, and jack pine were infested more severely than the others. Tip moth in the larva stage bores into terminal shoots and buds of various conifers killing back the terminal growth. If infestations of this insect occur for several years, height growth and form will be seriously affected. After the trees reach a height of about 25 feet, the tip moth does little damage.

In general the mortality caused by rabbits and rodents in the planting studies was very small, but they did cause heavy damage

in local areas (fig. 8). Sweetgum was planted in 1947 in area 12 but the planting was a complete failure due to severe rabbit damage. Rodents can be especially harmful to planted tree seeds. Rabbit and rodent populations are cyclic and planting should be deferred until extremely high peaks of population have passed.

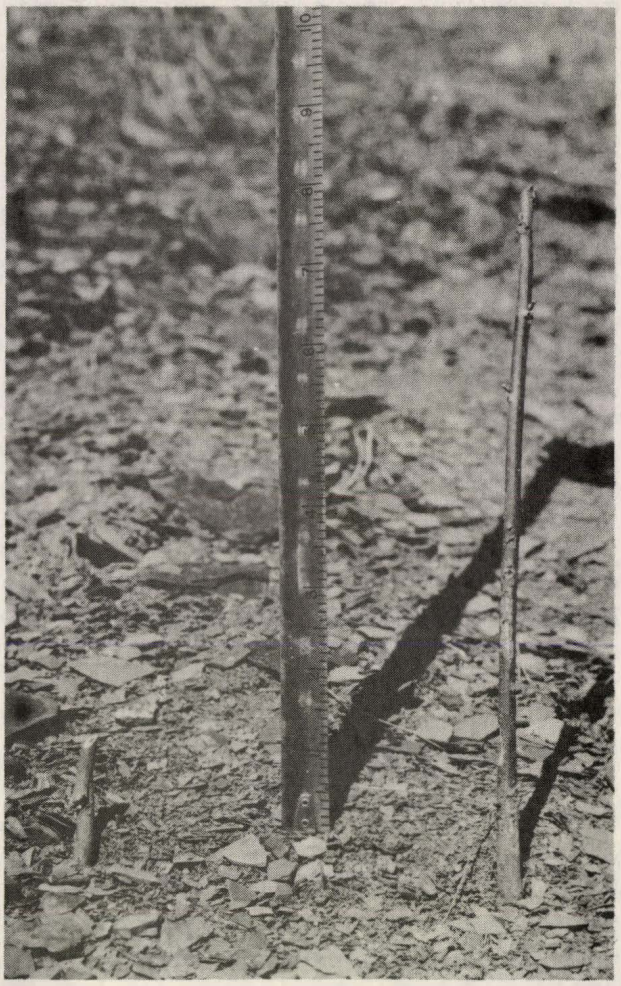


Figure 8.--Two black walnut seedlings in the Mixed-Planting Study with typical rabbit injury. Unless repeated consistently, this damage is not important because new shoots may be produced.

Although damage has not been noted in the Species-Suitability Test, trees in older plantings of ponderosa pine have been severely attacked by a needle cast fungus (fig. 9). This fungus kills needles, and if severe enough, completely defoliates and kills the tree. This, coupled with the low survival of planted ponderosa pine in the Species-Suitability Test, discourages using this species in strip-mine planting.

Planting area 6 burned at least four times during the 6 years after planting. Although many of the trees sprouted after the tops were killed, survival and growth of all species were greatly reduced. Plantations must be protected from wild fires if they are to be successful.

FOREST PLANTING RECOMMENDATIONS

The foregoing information has been presented in the hope that it will help owners and managers of strip-mined land decide whether or not to try forestation as a means of making this land productive again. Once it has been decided that forest tree planting offers the best means of rehabilitating a particular area, one of the first questions is what species to plant. The over-all objective of the planting must be carefully considered when selecting the species to be used. Is the planting for aesthetic or wildlife habitat improvement, Christmas tree production, post production, or is it being made for the production of lumber or other wood products? It is possible that several of these objectives may be attained in a single planting.

Spacing and Planting Method

Spacing in plantings for general post and timber production should average about 7 by 7 feet. In eroding areas spacing should be closer in order to get a crown cover as soon as possible. If a Christmas tree planting is being made, the trees will be fairly young when cut; consequently, spacing may be as close as 4 by 4 feet. Spacing should be varied where necessary to avoid planting toxic acid spots, narrow ridgetops, and places where water is likely to stand. If survival is less than 50 to 60 percent after the first growing season, it would be advisable to replant failed spots the following spring. For the general conditions existing on strip-mined banks in this area, the side-hole method of planting is recommended. Planting may be started as early as the middle of February in Oklahoma and may be continued until the middle of April in northern Missouri.

Post Plantings

The area of Kansas, Missouri, and Oklahoma where strip mining is concentrated is farmed intensively, so fence posts are in great demand. Many of the posts used here are shipped in from outlying areas, although some come from locally grown trees. The primary "homegrown" post is Osage-orange (Maclura pomifera (Raf.) Schneid.), grown in hedges planted by the early farmers. During the past 10 years many of the hedge rows have been removed to increase crop production. Hedge rows will not continue to supply as many posts as they have in the past (8). One way to increase future yields of homegrown posts is by planting post-producing species on strip-mined land.

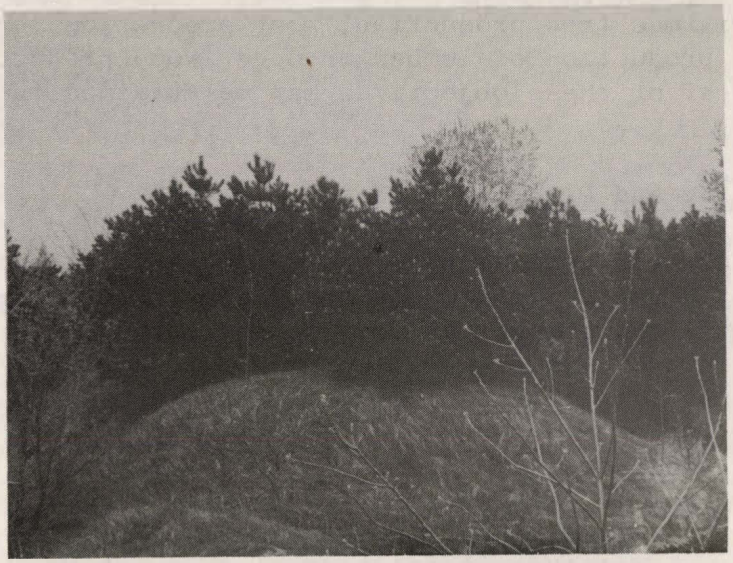
Some advantages of producing posts on strip-mined land are:

1. A relatively short rotation. Posts can be produced in 8 to 15 years.

2. Reproduction for successive crops of posts can often be obtained through sprouting.

3. Markets are readily available or the posts can be used on the planter's own land.

In addition, materials cut when thinning plantations established primarily for timber production can often be utilized for posts.



Ponderosa pine were growing vigorously 14 years after planting in Crawford County, Kansas.

But 18 years after planting all of the trees in the same stand were infected with a fungus and many had died.

Figure 9.--Ponderosa pine is highly susceptible to needle-cast fungus.

Christmas Tree Plantings

Increased popularity in the midwest of various pines for use as Christmas trees has stimulated interest in making plantings in this area for the production of Christmas trees for local markets. Such plantings have a short rotation when compared to timber production and there is a high potential return. As in most tree-planting ventures, there are hazards. There are so many unanswered questions pertaining to quality production and marketing that the planter is advised to limit planting for this purpose to small acreages.

Mixed Plantings

Depending upon the objectives of the planting, it may be desirable to plant several species in mixture. Trees planted in mixture usually have better form than those grown in pure stands. The use of several species spreads the risk of failure of the individual species, and advantage can be taken of the abrupt changes in topography in strip-mined land by selecting species with different moisture requirements.

Black locust has shown much promise as a primary component of mixed plantings. It grows fast, can produce posts at an early age, and according to Chapman (1) and Finn (4), benefits associated trees by increasing the amount of nitrogen in the soil. Locust can be planted on the upper slopes; species, such as black walnut, that require a moist site for best development can be planted on the lower slopes and broad bottoms. Stands of black locust that have been severely infested by the borer may be underplanted with such tolerant species as black walnut, bur oak, and black cherry.

Species Recommended for Planting

Tree planting on strip-mined land is relatively new in Kansas, Missouri, and Oklahoma so much information and time will be required before recommendations on what species to plant can be made with any great degree of confidence. However, experimental plantings, stands established through natural seeding, and experience of others in nearby areas have given some clues as to what species are most likely to produce a crop on strip-mined land in the 3-state area. The following recommendations, although tentative, are based on the best information available and should be of some help to those who must decide what trees to plant.

Green ash.--Survival and growth of this species are good on most sites; however its best development is in moist locations. It does well even when it has moderately heavy competition from shrubs and herbaceous cover. It can be grown in mixed plantings with black locust or other hardwoods. It grows rapidly and can be used where

a quick cover is desired for site protection (fig. 10). Such products as crating and boxing, handle stock, and rough lumber can be obtained from merchantable-size trees.

Black walnut.--Past plantings of walnut have indicated that it can be established satisfactorily. It can be grown from seedlings or seeds. If seeds are used, two or three seeds should be planted per spot to insure better stocking. For best results it should be planted in the more moist locations on the banks. It tolerates heavy herbaceous competition and can be used for underplanting deteriorated black locust stands. Tree form and wood quality are best when walnut is grown in mixture with other species. This tree provides early crops of nuts usable both by man and wildlife. Large trees of good quality command high prices for veneer, furniture, and gunstock material.

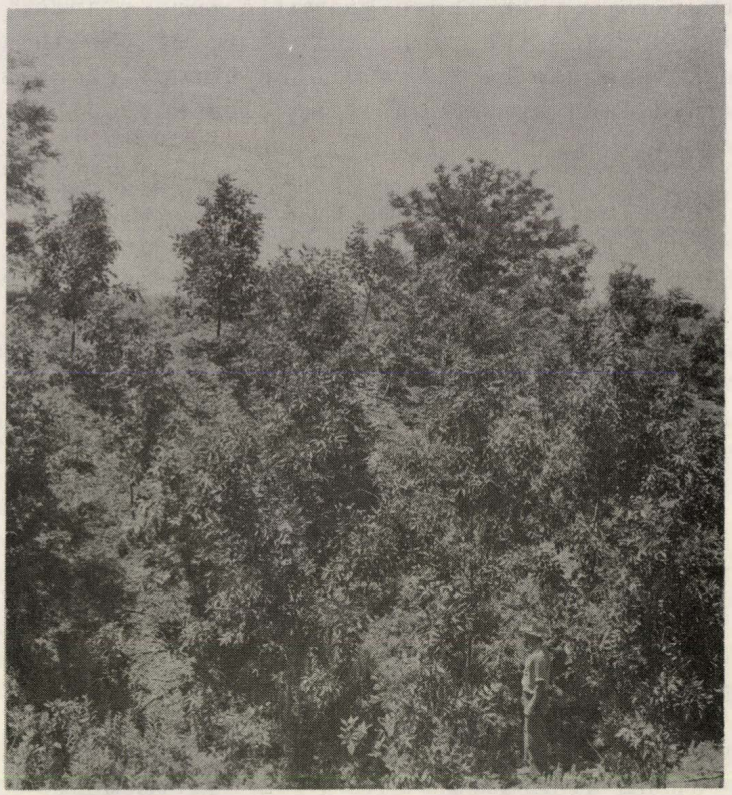


Figure 10.--Growth of this 6-year-old green ash on area 11 has been rapid and the stand will soon close.

Eastern redcedar.--Best development of this species is on calcareous and mildly acid banks. Growth is slow if planted on strongly acid sites. It is tolerant of moderate competition. Cedar has some value in providing food for wildlife and produces good, durable fence posts that are readily marketable. In some areas cedar Christmas trees (fig. 11) can be sold, and there is a ready market for small sawtimber-size trees for novelty and specialty products. Eastern redcedar is the alternate host for cedar-apple rust so this tree should not be planted within a mile of an orchard.

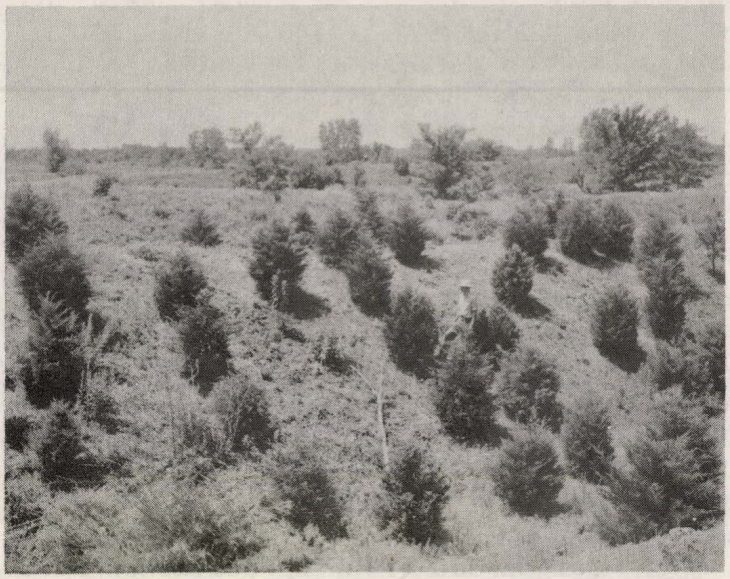


Figure 11.--Six years after planting, many of these eastern redcedars are suitable for Christmas trees (area 11).

Sycamore.--Volunteers of this species and trees planted experimentally have shown promise of easy establishment and rapid growth on many areas. Best growth is obtained on moist sites. It cannot be established satisfactorily under heavy cover but it may be planted in mixture with black locust and other species. Sycamore can be used for rough lumber and container veneer.

Bur oak.--This species can be established with seeds or seedlings; however, it may be wise to use two or three seeds per spot in order to get a fully stocked stand. It will grow on most of the banks in the area and tolerates heavy competition from herbaceous cover. Bur oak grows well in mixture with black locust and other species. The acorns produced by this species are good wildlife food. Rough lumber, stave bolts, and flooring can be produced from bur oak timber.

Black locust.--Locust will survive on all plantable sites in the area. Growth rate varies among sites but it will be rapid compared to other species (fig. 12). Planting in very dense cover should be avoided. Since growth is rapid, locust affords protection to the site within a few years. It is very susceptible to infestation by the locust borer; these infestations can completely destroy a merchantable crop. Where infestations are not serious, locust will usually produce excellent post crops within 8 to 12 years. This species is important as a nurse crop. Locust increases the amount of nitrogen available to plants and, because of rapid growth, produces a litter cover in a short time. Other species when planted in mixture with locust benefit from these improved growing conditions.

Figure 12.--This 3-year-old plantation of black locust in Wagoner County, Oklahoma, has a high survival and excellent growth. Even at this early age the stand is nearly closed.

Cottonwood (Populus deltoides Bartr.).--This species has seeded-in naturally on many areas and is growing rapidly (fig. 13). Cottonwood is suitable for all plantable strip-banks. It should not be planted where it will have intense competition. It may be used for rough lumber, container veneer, box wood, or pulpwood; however, there is no ready market for this species within the area at present except as saw logs.

Black cherry.--Black cherry will grow best on moist sites and it is tolerant of competition. It should be planted in mixture with other species and may be underplanted in deteriorated black locust stands. It is a good source of wildlife food, and under favorable conditions will produce high-quality furniture stock and veneer.

Other species.--There are several other species that have some promise but experience with them is limited. They should be planted only on a small scale until more is known of their suitability to strip-mined land conditions. Catalpa (Catalpa spp.), Osage-orange, and mulberry (Morus spp.) make excellent fence posts and may well be planted for that purpose. All of these species have been found growing naturally in mixed stands on banks throughout the area.

Silver maple (Acer saccharinum L.) is well adapted to moist sites and it has been frequently found growing naturally. It can be used for rough lumber, box wood, and container veneer.

Scotch pine (Pinus sylvestris L.) and jack pine have been grown successfully for Christmas trees within the area on undisturbed land; these and other conifers may have some value in such short-rotation plantings on strip-mined land.

SUMMARY

Strip-mined land in Kansas, Missouri, and Oklahoma lies within a prairie-forest transition zone; therefore, it is logical to look to these two types of cover as a means of rehabilitating such land. However, the discussion in this paper is limited to the possibilities of using strip-mined land for growing forest crops. Information on the survival and early growth rate of several species of trees planted at various locations in the 3-state area has been obtained from two experiments.

Most of the mortality took place during the first growing season after planting. Mortality in succeeding years was insignificant.

Acidity is of primary importance to the survival and growth of trees. Although there are relatively few areas that contain a high percentage of toxic material near the surface, it is important to be able to recognize such areas and avoid planting them.

Figure 13.--This 12- to 14-year-old natural cottonwood stand has good stocking and the trees have grown rapidly.

Texture, more specifically the percent of soil-size particles, has an effect on the moisture retention capacity and the erodability of the banks. Areas having a high percentage of small particles are more likely to erode, especially during the first few years after stripping. Such areas should be allowed to stabilize at least 2 to 5 years before planting.

Two of the planting areas were used to test the effects of grading on the survival and growth of planted trees. Survival and growth on undisturbed strip-banks were better than on graded banks. The moisture relationships were poorest on the graded banks.

Survival was poorest on ridgetops and bottoms and best on the slopes. Ridgetops are dry and barren and seedlings on these locations are exposed to extremely high temperatures while seedlings planted in the bottoms may be subjected to heavy herbaceous competition or may be growing in water-logged soil. Height growth was poorest on the ridgetops.

Natural cover affects different species in different ways. Moderate amounts of cover seem beneficial to most species but heavy cover may choke out species not able to withstand competition.

In general, those species that were native to the area survived best. Plantings of species not native to the general area should be made on a trial basis only.

Differences in the amount and distribution of rainfall may account for the differences in the survival between the two experimental plantings established during different growing seasons.

Tentative recommendations for establishing plantations based on the best available information are presented. As experimental plantings become older more definite recommendations can be made.

LITERATURE CITED

(1) Chapman, A. G.
1944. Forest planting on strip-mined coal lands with special reference to Ohio. Central States Forest Expt. Sta. Tech. Paper 104. 25 pp.

(2) Deitschman, Glenn H., and Lane, R. D.
1952. Forest planting possibilities on Indiana coal-stripped lands. Central States Forest Expt. Sta. Tech. Paper 131. 57 pp.

(3) ---------- and Neckers, J. W.
1953. Identification and occurrence of sulphides on land stripped for coal. Central States Forest Expt. Sta. Tech. Paper 136. 21 pp.

(4) Finn, Raymond F.
1953. Foliar nitrogen and growth of certain mixed and pure forest plantings. Jour. Forestry 51(1):31-33.

(5) Kohnke, Helmut
1950. The reclamation of coal mine spoils. Advances in Agron. 2:317-349.

(6) Limstrom, G. A.
1948. Extent, character, and forestation possibilities of land stripped for coal in the Central States. Central States Forest Expt. Sta. Tech. Paper 109. 79 pp.

(7) ----------
1952. Effects of grading strip-mined lands on the early survival and growth of planted trees. Central States Forest Expt. Sta. Tech. Paper 130. 35 pp.

(8) Quigley, Kenneth L., and Clark, F. Bryan
1951. Fence posts, a potential market for Missouri pine timber. Mo. State Div. Resources and Devlpmt. 9 pp.

(9) Rogers, Nelson F.
1949. The growth and development of black walnut (Juglans nigra L.) on coal strip-mined land in southeastern Kansas. Kans. Acad. Sci. Trans. 52(1):99-104.

(10) ----------
1951. Strip-mined lands of the Western Interior Coal Province. Mo. Agr. Expt. Sta. Res. Bul. 475. 55 pp.

APPENDIX

(Additional tables from the Species-Suitability Test)

Table 4.--Location and description of experimental planting areas

State and area number	County	Coal seam	Year mined	Acidity[1]	Texture[2]	Soil-size particles	Natural cover[3]
						Percent	Percent
Missouri							
1	Randolph	14	1945	M	C	57	30
2	Bates	18	1932	C	SL	40	35
3A	Bates	18	1942	Mi	SL	52	50
3B	Bates	18	1942	A	SL	32	5
4	Henry	9	1946	A	C	50	5
5	Barton	6	1935	A	SL	43	95
6	Barton	6	1930	A	SL	47	95
Kansas							
7	Crawford	6	1945	M	SL	17	5
8A	Crawford	9	1939	A	SL	36	30
8B	Crawford	9	1939	A	SL	39	30
9	Crawford	14	1933	A	SL	50	40
10	Cherokee	9	1942	A	SL	40	25
11	Cherokee	14	1941	A	SL	37	40
Oklahoma							
12	Wagoner	12	1934	A	SL	47	95

1/ (Toxic - more than 75 percent of surface material has a pH of less than 4.0.)
M (Marginal) - 51-75 percent of surface material has a pH of less than 4.0.
A (Acid) - more than 50 percent with a pH of 4.0-6.9.
C (Calcareous) - more than 50 percent with a pH of more than 7.0.
Mi (Mixed) - less than 50 percent of any of the above classifications.

2/ C - clay; SL - silty loam.

3/ Visual estimate of the density of natural cover during the first growing season.

Table 5.--Average survival six growing seasons after planting by species and planting areas

(In percent)

Species	Planting areas													Average
	1	2	3A	3B	4	5	7	8A	8B	9	10	11	12	
Black cherry	16	24	23	9	69	75	41	60	17	29	5	34	26	33
Black locust	38	78	67	76	92	79	73	85	68	67	57	71	50	69
Black walnut seed	-	13	5	2	11	22	16	13	5	25	13	34	17	15
Bur oak seed	1/25	19	3	-	21	30	8	32	42	32	23	33	25	24
Bur oak	1/25	28	26	20	45	78	68	-	-	62	31	38	1/34	41
Green ash	55	57	47	68	59	79	65	54	46	84	74	67	43	61
Sycamore 1/	18	18	13	12	35	48	61	54	74	64	72	71	8	42
Eastern redcedar	32	40	25	29	64	67	48	49	40	17	39	49	47	42
Jack pine	1/21	11	0	0	38	1/44	47	22	9	23	31	16	1/0	20
Loblolly pine	-	1/42	-	-	8	1/93	18	9	9	26	15	11	1/12	24
Pitch pine	20	29	6	0	46	26	78	41	15	38	36	49	-	32
Ponderosa pine	10	-	0	0	25	21	21	18	5	23	14	1	0	12
Shortleaf pine 1/	12	24	1	0	33	68	36	44	29	25	55	56	16	31
Virginia pine	1/17	13	0	0	57	34	32	43	4	32	42	21	1/16	24
Average	24	30	17	18	43	55	44	40	28	39	36	39	23	34

1/ Planted in 1948--5-year survival.

Table 6.--Average survival six growing seasons after planting by topographic position[1/]

Species	Ridgetops	Bottoms	North and east slopes	South and west slopes
	Percent	Percent	Percent	Percent
Black cherry	36	20	43	40
Black locust	76	47	68	74
Black walnut seed	7	13	19	18
Bur oak seed	13	17	28	22
Bur oak	43	42	47	40
Green ash	50	67	67	64
Sycamore[2/]	45	38	45	37
Eastern redcedar	29	37	53	42
Jack pine	10	10	39	24
Loblolly pine	22	14	32	21
Pitch pine	30	18	43	27
Ponderosa pine	7	10	15	13
Shortleaf pine[2/]	26	14	30	35
Virginia pine	25	14	36	36
Average	30	26	40	35

1/ Graded areas 3B and 8B are not included.
2/ Planted in 1948--5-year survival.

Table 7.--Survival after the first growing season by species and natural cover classes[1/]

Species	Percent natural cover[2/]			
	0 - 20	21 - 40	41 - 60	61 - 80[3/]
	Percent	Percent	Percent	Percent
Black cherry	55	78	90	73
Black locust	90	83	89	58
Black walnut seed	50	56	97	100
Bur oak seed	83	83	96	97
Bur oak	80	86	93	97
Green ash	80	84	90	88
Eastern redcedar	56	64	71	60
Jack pine	22	36	34	50
Loblolly pine	22	34	36	50
Pitch pine	34	52	67	58
Ponderosa pine	29	29	36	8
Virginia pine	42	52	64	60
Average	54	61	72	67

1/ Includes areas 2, 5, 6, 8A, 8B, and 9.

2/ Estimates of cover in the immediate vicinity of each planting spot.

3/ The 81-100 percent class has been omitted because of a lack of data.

Table 8.--Average total tree height six growing seasons after planting by species and planting areas

(In feet)

Species	Planting areas													Average
	1	2	3A	3B	4	5	7	8A	8B	9	10	11	12	
Black cherry	8.1	5.5	6.4	4.6	4.1	3.0	5.0	3.3	3.1	2.8	4.7	4.7	4.2	4.6
Black locust	18.0	11.9	19.4	15.7	18.4	19.6	14.4	16.0	13.4	20.1	16.8	20.0	13.8	16.7
Black walnut seed	-	2.8	4.9	4.3	3.2	2.2	2.6	2.1	1.2	2.4	2.9	3.6	2.7	2.9
Bur oak seed	1/3.9	4.5	2.4	-	2.9	1.6	5.3	3.6	1.1	3.8	3.0	1.9	2.3	3.0
Bur oak	1/5.9	4.0	4.1	4.3	3.8	4.0	5.4	-	-	3.7	5.1	3.5	1/1.9	4.2
Green ash	7.1	4.4	6.4	8.3	6.7	4.7	5.8	6.0	3.9	5.9	5.3	7.2	5.1	5.9
Sycamore 1/	8.2	6.9	10.1	4.9	5.3	6.4	7.1	5.7	4.1	7.2	7.3	7.5	5.2	6.6
Eastern redcedar	5.2	4.7	4.6	5.3	4.7	5.3	4.4	5.2	4.8	5.3	4.8	5.1	5.8	5.0
Jack pine	1/3.3	3.6	-	-	5.0	1/3.8	2.9	5.0	5.0	3.8	3.7	2.9	1/-	3.9
Loblolly pine	-	1/6.1	-	-	3.9	1/7.0	6.0	6.1	7.9	5.5	7.3	6.8	1/5.5	6.2
Pitch pine	5.7	4.4	2.5	-	3.0	5.4	5.8	3.5	2.7	4.6	5.7	2.7	-	4.2
Ponderosa pine	3.6	-	-	-	2.6	2.2	3.2	2.4	1.4	2.2	2.4	2.5	-	2.5
Shortleaf pine 1/	6.7	4.4	4.6	-	4.6	4.7	3.6	4.1	2.7	3.0	3.6	2.8	2.9	4.0
Virginia pine	1/6.1	4.4	-	-	6.8	6.8	4.5	6.9	4.4	4.6	4.1	7.0	1/3.9	5.4

1/ Planted in 1948--5-year survival.

Table 9.--Average height six growing seasons after planting by topographic position[1/]

Species	Ridgetops	Bottoms	North and east slopes	South and west slopes
	Feet	Feet	Feet	Feet
Black cherry	3.9	5.3	4.2	4.3
Black locust	14.2	21.1	17.5	17.8
Black walnut seed	2.9	3.0	2.7	2.8
Bur oak seed	2.8	2.0	3.3	3.0
Bur oak	3.6	3.8	4.3	4.3
Green ash	5.4	5.9	5.7	6.2
Sycamore[2/]	6.1	5.5	7.0	7.9
Eastern redcedar	4.6	5.4	5.0	5.1
Jack pine	3.1	4.7	3.9	3.7
Loblolly pine	5.5	4.2	7.0	5.8
Pitch pine	4.2	3.9	5.4	4.4
Ponderosa pine	2.1	1.8	2.7	2.7
Shortleaf pine[2/]	3.2	4.1	4.2	3.8
Virginia pine	5.7	5.5	5.9	5.9
Average	4.8	5.4	5.6	5.6

1/ Graded areas 3B and 8B are not included.
2/ Planted in 1948--5-year growth.

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